Evaluation of Ozone Injury
On Vegetation in the
Mingo National Wildlife Refuge
Missouri

2004 Observations

Submitted to

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INTRODUCTION

General

The Mingo National Wildlife Refuge (Mingo NWR) is one of more than 500 refuges in the NWR System administered by the U. S. Fish and Wildlife Service (FWS). The NWR System is a network of lands and waters managed specifically for the protection of wildlife and wildlife habitat and represents the most comprehensive wildlife management program in the world. Units of the system stretch across the United States from northern Alaska to the Florida Keys and include small islands in the Caribbean and South Pacific. The character of the refuges is as diverse as the nation itself.

The Mingo refuge is located in portions of Stoddard and Wayne Counties in southeast Missouri, approximately 150 miles south of St. Louis (Figure 1). The refuge was established in 1945 under authority of the Migratory Bird Treaty Act as a resting and wintering area for migratory waterfowl. The NWR contains 21,676 acres and lies in a linear basin formed in an ancient abandoned channel of the Mississippi River. The area is predominantly a bottomland hardwood swamp, bordered on the west by the foothills of the Ozark Uplift and on the east by a terrace named Crowley's Ridge. Elevations along the top of these ridges range as high as 405 feet above mean sea level (MSL) compared to the basin floor's 340 feet above MSL.

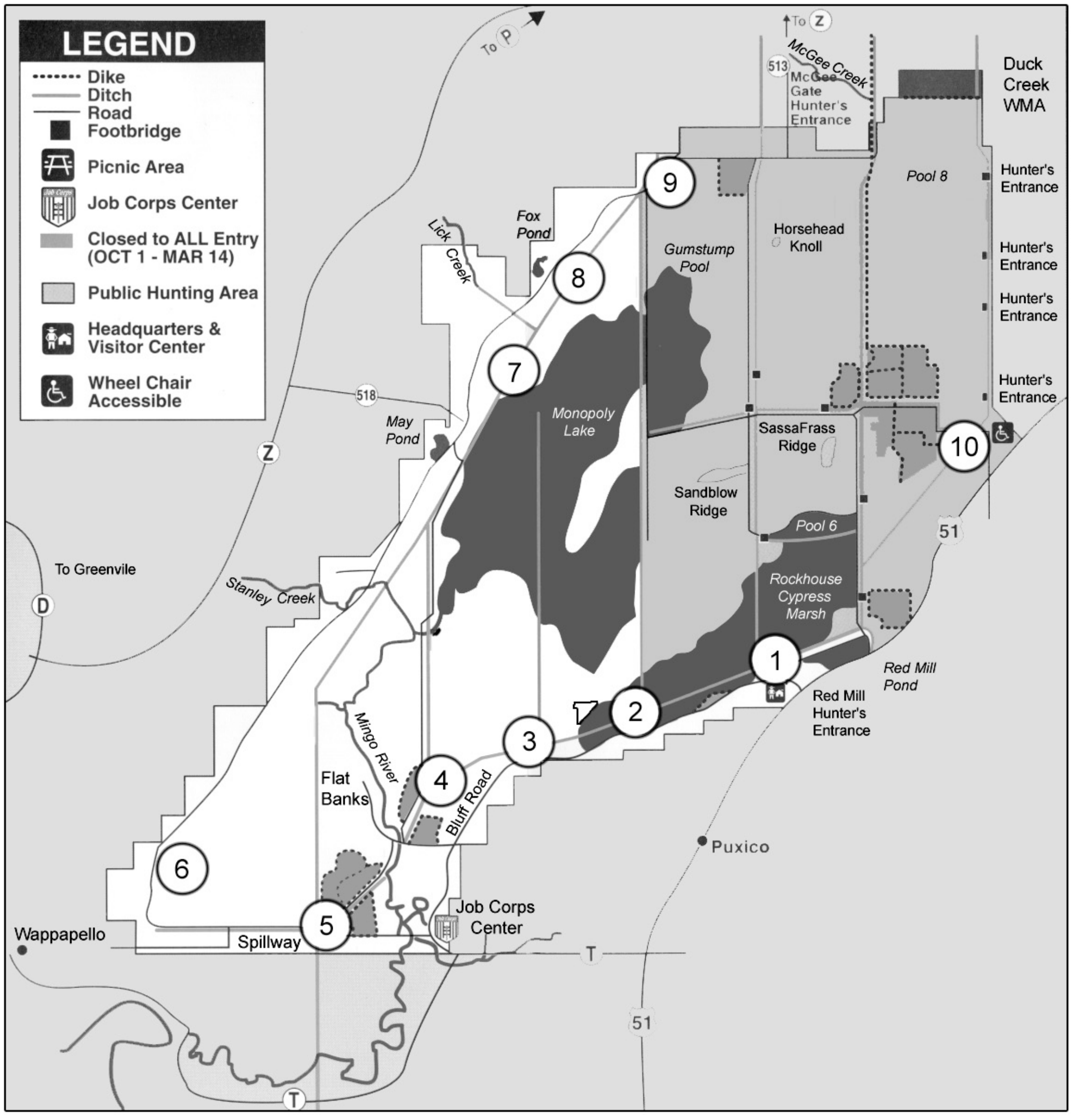

Figure 1. General map of the Mingo National Wildlife Refuge and location of survey plots.

Objectives

1). To identify ozone–sensitive plant species in the Mingo NWR

2). To evaluate the incidence and severity of ozone injury on vegetation in the Mingo NWR

Justification

In 1978, Mingo Wilderness was designated a Class I air quality area under the Clean Air Act. Congress gave FWS and the other Federal land managers for Class I areas an "…affirmative responsibility to protect all those air quality related values (including visibility) of such lands...” Air quality related values include vegetation, wildlife, water, soils, visibility, and cultural resources. Despite this special protection, many of the resources in these wilderness areas are being impacted or have the potential to be impacted by air pollutants. Because many air pollutants can be carried long distances in the atmosphere, even rural and remote areas such as wilderness areas can be affected by air pollution.

To better understand how air pollution affects resources at the Mingo NWR, surveys were conducted in 1998- 2000, and 2003-2004 to evaluate ozone injury to vegetation within the refuge.

Diagnosis of Air Pollution Injury on Plants

Although many gaseous air pollutants are emitted into the atmosphere, only certain ones are phytotoxic and induce characteristic leaf symptoms that are useful during field surveys. The most important of these gaseous, phytotoxic air pollutants are ozone, sulfur dioxide, and fluorides. These pollutants, along with the normal constituents of the air, are taken into the plant leaf through the stomata. Once inside the leaf, the pollutant or its breakdown products react with cellular components causing tissue injury or death.

The resulting macroscopic symptoms, which are visible on the leaf surface, are classified as chronic or acute depending upon the severity of injury. Chronic symptoms imply tissue injury, whereas acute injury signifies tissue death. Chronic symptoms on foliage usually result a plant’s exposure to low levels of pollution for an extended time, or occur when a plant is somewhat resistant to a pollutant. Visible ozone injury is usually considered to be chronic injury. Acute injury may be observed following a short-term, high concentration of pollution, or occurs when a plant is in a very sensitive condition. Sulfur dioxide injury as observed in the field is often acute.

Macroscopic leaf injury caused by air pollutants often represents an intermediate step between initial physiological events and decreases in plant productivity. Decreases in plant productivity (Pye 1988) may result in ecological changes, such as reduced diversity (Rosenberg et al. 1979). Visible leaf symptoms induced by phytotoxic pollutants serve as important diagnostic tools that allow observers to identify specific air pollutants as causal agents of vegetation damage (Davis 1984; Skelly et al. 1987, Skelly 2000). This knowledge can be used in the air pollution emissions permitting process for siting new industries (i.e. Prevention of Significant Deterioration Program), assessment of the secondary air quality standards, assessing the presence of air pollution injury in Class I areas, and in litigation involving air pollution injury.

Although ozone was the air pollutant of concern in this survey, it should be recognized that phytotoxic levels of air primary pollutants such as sulfur dioxide and fluorides might occur near industrial sources. Likewise, trace elements including metals may be found in excessive levels in vegetation growing in areas downwind from industrial or urban sources (Davis et al. 1984, Davis et al. 2001). Toxic elements such as arsenic, mercury (Davis et al. 2002), selenium, and lead may be especially important in areas being managed for wildlife. Although such compounds are of more interest in mammalian and avian toxicity as compared to phytotoxicity, vegetation may sorb such contaminants and become part of the contaminated food chain. However, the presence of excessive trace elements such as metals, as well as organic biohazards such as dioxins and furans, is determined with laboratory analysis of foliage, not with surveys dealing with macroscopic foliar injury.

Ozone

Ozone is probably the most important and widespread phytotoxic air pollutant in the United States, and is the air pollutant most likely to have an easily recognizable impact on vegetation within a NWR. Background levels of ozone exist naturally in the lower atmosphere, possibly originating from vertical downdrafts of ozone from the stratosphere, lightning, or chemical reactions of naturally occurring precursors. However, in many areas, precursors leading to phytotoxic levels of ozone originate from upwind urban areas. In those areas, hydrocarbons and oxides of nitrogen are emitted into the atmosphere from various industrial sources and automobiles. These compounds undergo photochemical reactions in the presence of sunlight forming photochemical smog, of which ozone is a major component. Ozone, or its precursors may travel downwind for hundreds of miles during long-range transport, as influenced by wind direction and movement of weather fronts. Thus, ozone impinging on refuges may originate in areas many miles upwind from the refuge. In fact, concentrations of ozone are often greater in rural areas downwind from urban areas, as compared to within an upwind urban area, due to the presence of reactive pollutants in the urban air that scavenge the ozone.

There are certain bioindicator plants in the East that are very sensitive to ozone and exhibit characteristic symptoms when exposed to ozone (Anderson et al. 1989, Davis and Coppolino 1976, Davis and Skelly 1992, Davis et al. 1981, Davis and Wilhour 1976, and Jensen and Dochinger 1989). The principal investigator in this survey routinely uses the following broad-leaved bioindicator species for evaluating ozone injury: black cherry (*Prunus serotina*), common elder (*Sambucus canadensis*), common milkweed (*Asclepias syriaca*), grape (*Vitis* spp.), white ash (*Fraxinus americana*), and yellow-poplar (*Liriodendron tulipifera*). The investigator also uses, but less commonly, Virginia creeper (*Parthenocissus quinquefolia*) and *Viburnum* spp.

Ozone-induced symptoms on broadleaved bioindicators usually appear as small 1 - 2 mm diameter "stipples" of pigmented, black or reddish-purple tissue, restricted by the veinlets, on the adaxial surface of mature leaves (see Skelly 2000, Skelly et al. 1987). Immature leaves seldom exhibit symptoms, whereas mature leaves of sensitive species may show severe symptoms. To the casual observer, ozone-induced symptoms are similar to those induced by other stresses (e.g., moisture stress, nutrient deficiency, fall coloration, heat stress, as well as certain insects, and diseases). However, the pigmented, adaxial stipple on plants of known ozone-sensitivity (i.e., black cherry or grape) is a reliable diagnostic symptom that can be used to evaluate ozone injury.

On eastern conifers, the most reliable symptom (current-year needles only) induced by ozone is a chlorotic mottle, which consists of small patches of chlorotic tissue interspersed within the green, healthy needle tissue. The mottle usually has a “soft edge” (as opposed to a sharply defined edge) to the individual mottled areas. An extremely sensitive plant may also exhibit needle tip browning. However, this latter symptom can be caused by many stresses and is not a reliable diagnostic symptom. Conifer needles older than current-growing season needles are not useful as monitors, since over-wintering and multi-year insect injuries may produce confounding symptoms. Ozone injury on monocots such as grasses (i.e., *Spartina* sp.) is also very difficult to diagnose in the field, as there are many causal agents that can result in tipburn and chlorotic mottle on grasses.

Description of Refuge

(SOURCE: McCrea, Edward J., Interpretive Specialist, Mingo National Wildlife Refuge, "Inventory of Interpretive Resources", 15 December 1972)

General

Historically, the Mingo NWR was a haven for wildlife before logging, drainage, and conversion to agriculture altered the area. Bankruptcy of the Mingo Drainage District in the 1930s set the stage for federal acquisition and subsequent restoration of the swamp and its productivity. Peak waterfowl populations of 125,000 mallards and 75,000 Canada geese have been recorded. The refuge contains approximately 15,000 acres of bottomland hardwoods, 1,275 acres of cropland and moist soil units, 700 acres of grassland, and 5,000 acres of marsh and water. Seven natural areas and 99 archaeological sites have been identified on the refuge. In 1976, 7,730 acres were designated as a wilderness area.

Trees, Shrubs, and Vines

Although oaks are the most prevalent species of trees on the refuge (more than 20 species), a wide variety of woody plants are to be found throughout the area. In the lowest parts of the refuge, tupelo and bald-cypress trees are common. Pin, willow, overcup, cherrybark, and swamp white oaks, as well as swamp cottonwood, red maple, water locust, and ash occur on the slightly higher areas. River birch, sycamore, and devil's walking-cane are other distinctive lowland species. On the uplands, white oaks, red oaks, and several species of hickory are prevalent, and are associated with occasional black cherry, yellow-poplar, persimmon, sweetgum, and black gum.

Most of the trees on the Mingo NWR are not large. The area had been cut-over and burned before the refuge was created, and some timber harvesting has continued. The larger stands of cypress and tupelo on the refuge are composed mostly of young trees. However, fairly mature stands of timber exist in areas that have not been cut-over since the refuge was created. However, 18 state champion trees are found on the refuge, including two national champions.

The two most common shrubs in the refuge’s low-lying areas are buttonbush and willow. Swamp privet, deciduous holly, and wahoo are also present. Red-buckeye, dogwood, redbud, sumac, spicebush, and winterberry holly are common on the upland sites. Several vines of interest occur on the refuge, including trumpet creeper with its showy orange flowers, poison-ivy, cat briars, clematis, and several species of grape. Buckwheat-vine (Brunnichia cirrhosa), which is usually found farther south, is also common on the refuge.

Herbaceous Plants

Wildflowers are abundant, and many showy varieties can be seen from refuge roads. Trout lilies, wild ginger, dutchman's breeches, trillium, violets, spring beauty, blood-root, jack-in-the-pulpit, and green dragon are prevalent in the spring. The area near the bluffs on the east side of the refuge is a particularly good place to see a variety of spring wildflowers. By early summer, dense vegetation covers most of the refuge, and wildflowers are no longer as prevalent. The most visible flowers throughout the summer months are tall bellflower, cardinal flower, great blue lobelia, and spotted jewelweed. Purple-fringeless orchid and spider-lily are two showy but less common summer wildflowers of the refuge.

Spider-lily in particular is a large, spectacular flower that is listed as rare in most areas of the south. It has been found in five or six locations on the refuge, and has been noted (and photographed) by the investigator at two locations on the refuge. In the wetter areas, American lotus frequently covers acres with its large yellow flowers and prominent leaves. Arrowhead, creeping willow, primrose, and mallow are other common rooted aquatics. The surface of many refuge waterways is covered by a thick green mass of floating aquatics--mainly duckweed, Wolffiella, and Spirodella.

Fungi, Mosses, Lichens, and Ferns

Although little taxonomic work has been done on the Mingo NWR with the lower plants, the refuge possesses a great number of mosses and lichens. During early fall in particular, a walk through the damp woods reveals many colorful fungi. Twelve different species of ferns have been found on the refuge. The dolomite bluffs are productive areas for ferns, with some of the more distinctive kinds, such as walking fern, being found there.

METHODS

General Survey Areas

It had been predetermined that survey sites had to occur in open-areas (such as those occurring along roads or in fields), where ozone-sensitive plant species grew in sunlight and exposed to unrestricted air movement (Anderson et al. 1989; USDA Forest Service, 1990). Immediately prior to the August 1998 survey, the investigator met with Mingo NWR personnel. During this time, maps were viewed and discussed with refuge personnel. Based on these initial discussions, potential survey areas were selected in 1998. These general areas, with modification, have been used since and were used in the 2004 survey.

Selection of Bioindicator Species

The plants found in the refuge are typical members of similar habitats throughout the area. Although many distinctive species are present, the similarity of habitat does not make for a particularly diverse flora. However, the refuge encompasses parts of Crowley's Ridge and the Ozarks in addition to the lowlands, adding abundant species diversity. Of particular interest is the fact that the Mingo NRW is situated on the "boundary" between several floristic provinces, and many species of plants and animals are at the limit of their range within the Mingo area. Plants at the edge of their normal range may be more at risk from stresses such as air pollutants, as compared to plants growing well within their natural range.

A list of flora, containing both woody and non-woody species, was furnished by the FWS (Appendix 1). In addition, Thompson (1980, Appendix 2) published an extensive survey of the refuge’s woody flora. The first list includes plants that can be expected to occur in the area according to Steyermark (1963), the leading authority on Missouri flora. While every plant listed by Steyermark has not been identified on the refuge, the list is considered to be representative of the refuge flora (McCrea 1972).

Prior to the 1998 survey, an initial selection of potential bioindicators that might exhibit ozone injury in the survey area was selected from these two lists, as well as by conferring with refuge personnel. Plant species or genera tentatively selected as bioindicators included: ash (*Fraxinus* sp.), black cherry (*Prunus serotina*), blackberry (*Rubus* sp.), common milkweed (*Asclepias syriaca*), cucumbertree (*Magnolia acuminata*), flowering dogwood (*Cornus florida*), grape (*Vitis* sp.), mulberry (*Morus* sp.), persimmon (*Diospyros virginiana*), poison-ivy (*Rhus* *radicans* = *Toxicodendron radicans*), redbud (*Cercis canadensis*), sassafras (*Sassafras albidum*), sweetgum (*Liquidambar styraciflua*), sycamore (*Platanus occidentalis),* tree-of-heaven (*Ailanthus altissima*), and winged sumac (*Rhus copallina*). Of course, many of the species listed grow in scattered localities through the NWR, and may not be present at designated survey sites; likely, they could be found only with help of local botanists. Also, it should be pointed out that most plant species growing in the wetter parts of the refuge have not been studied with regard to ozone-induced macroscopic symptoms. That is, the ozone-sensitivity of wetland species, as determined by controlled exposures of ozone, is generally unknown.

Based on observations made in the field during each year, other potential indicators were added, including cottonwood (*Populus* spp.), black-berried elder (*Sambucus canadensis*), fragrant sumac (*Rhus aromatica*), smooth sumac (*Rhus glabra*), Virginia creeper (*Parthenocissus quinquefolia*) and black walnut (*Juglans nigra*). Final selection of indicators was usually dictated by species abundance at accessible, open locations.

Air Quality

Ambient ozone monitoring data are useful to complement visual injury surveys. In general, when soil moisture is adequate, the amount of ozone-induced stipple may be positively correlated with ambient ozone concentrations during the growing season. However, more consistent and long-term monitoring datasets are needed to further understand the interactions between foliar symptoms and factors such as ambient ozone, plant species, time of year, and environmental conditions such droughts in our national wildlife refuges.

Ozone is not monitored within the Mingo NWR. The closest EPA monitoring site is located at Bonne Terre, Missouri (EPA AIRS Site #29-186-0005), where ozone has been monitored since April 1996. This monitoring site is located approximately 100 miles north of the Mingo refuge and about 50 miles south of St. Louis. Data from this ozone monitor must be used to estimate ozone levels impinging on the Mingo NWR, as it is the closest monitor.

In this report, ambient ozone levels will be expressed as “cumSUM60”, the cumulative sum of all hourly ozone concentrations equaling or exceeding 60 ppb, expressed as ppb.hrs. We have determined that this ozone statistic correlates with plant damage. During the years of survey, the cumSUM60 ozone levels at the Bonne Terre monitoring site were greatest in 1999, less in 1998, and least in 2004 (Figure 2). Ozone levels in 2000 and 2003 were intermediate.

The cumSUM60 ozone levels at Bonne Terre during the growing season of 1999 were very high, approaching 60,000 ppb.hrs by the end of August (Figure 2). In 1998, the ambient ozone levels approached 40,000 ppb.hrs by late August. In 2000 and 2003 the ozone levels were about 35,000–40,000 ppb.hrs by this time. During 2004, ambient ozone levels were very low, approaching only 14,000 ppb.hrs in late August.

Ozone levels in this part of Missouri continue to rise much later in the year than at many other refuges surveyed. In fact, the cumSUM60 ozone levels in 1999 actually reached 80,000 ppb.hrs by November (data not shown). The impact of this late-season ozone regime on vegetation, or other biota, is unknown.

For comparison to a refuge with extreme ozone concentrations, the ozone levels at the Edwin B. Forsythe NWR near Brigantine, New Jersey, reached about 80,000 ppb.hrs in 1991 (a very high ozone/drought year), and ozone levels were often greater than 40,000 ppb.hrs by the summer's end of many years. It appears that plants at both Mingo and Brigantine are exposed to very high levels of ambient ozone late in the growing season.

The ozone levels monitored at Bonne Terre in 1998-2004 are considered to be very high and capable of causing significant plant damage, in the absence of severe drought that results in stomatal closure. During drought periods, many plants close stomata to prevent water loss. However this stomatal closure also reduces gas uptake, including uptake of ozone, resulting in reduced ozone injury on the leaves. Figure 3 illustrates that there was adequate moisture in the refuge during 2004.

Even the lower ozone concentrations monitored early in the summer (i.e., during mid-June) during all survey years are considered phytotoxic levels to ozone-sensitive species of plants in the refuge. Assuming that the ozone levels monitored 100 miles away at Bonne Terre are similar to those within the Mingo NWR, ozone injury is likely to occur during most years on sensitive species of refuge vegetation. However, to my knowledge there had been no recorded surveys prior to my initial (1998) survey to document the presence of ozone injury within the Mingo NWR.

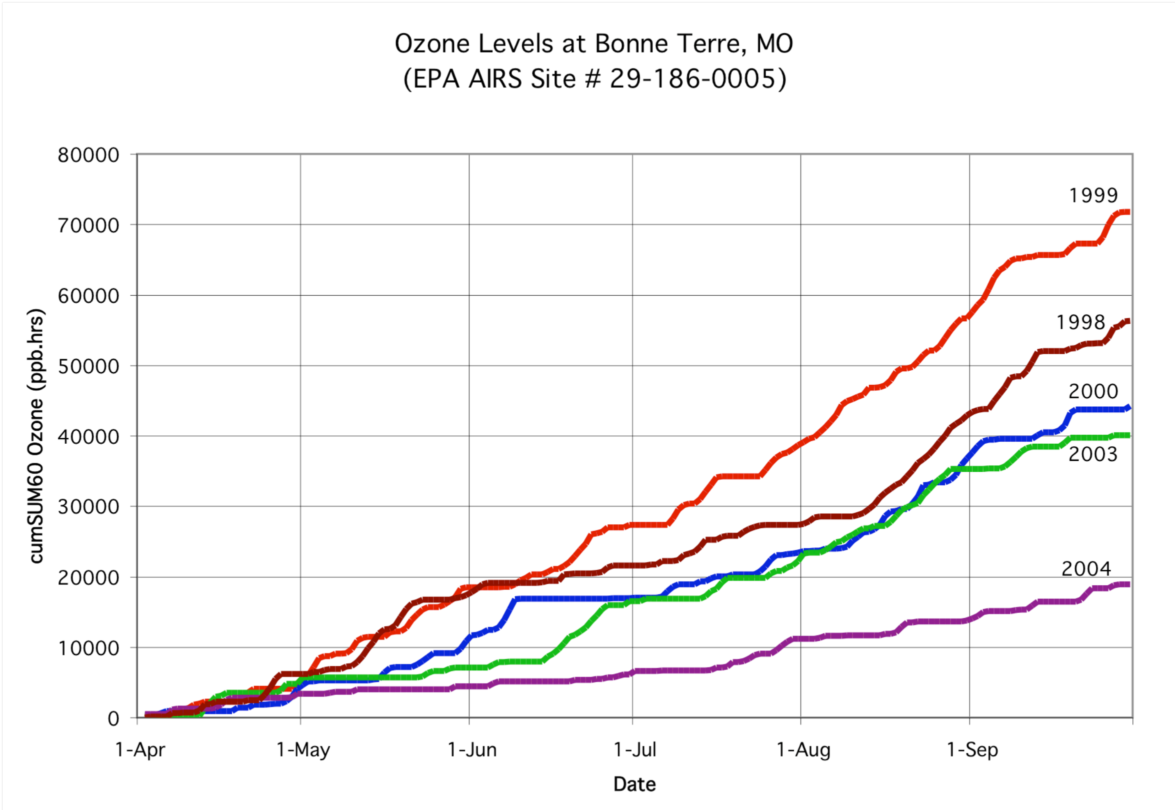

Figure 2. Cumulative sum of all hourly ozone concentrations equaling or exceeding 60 ppb (cumSUM60, ppb.hrs) monitored in 1998-2000 and 2003-2004 at Bonne Terre, MO (EPA AIRS Site # 29-186-0005). This monitoring site is located approximately 100 miles north of the Mingo refuge and about 50 miles south of St. Louis.

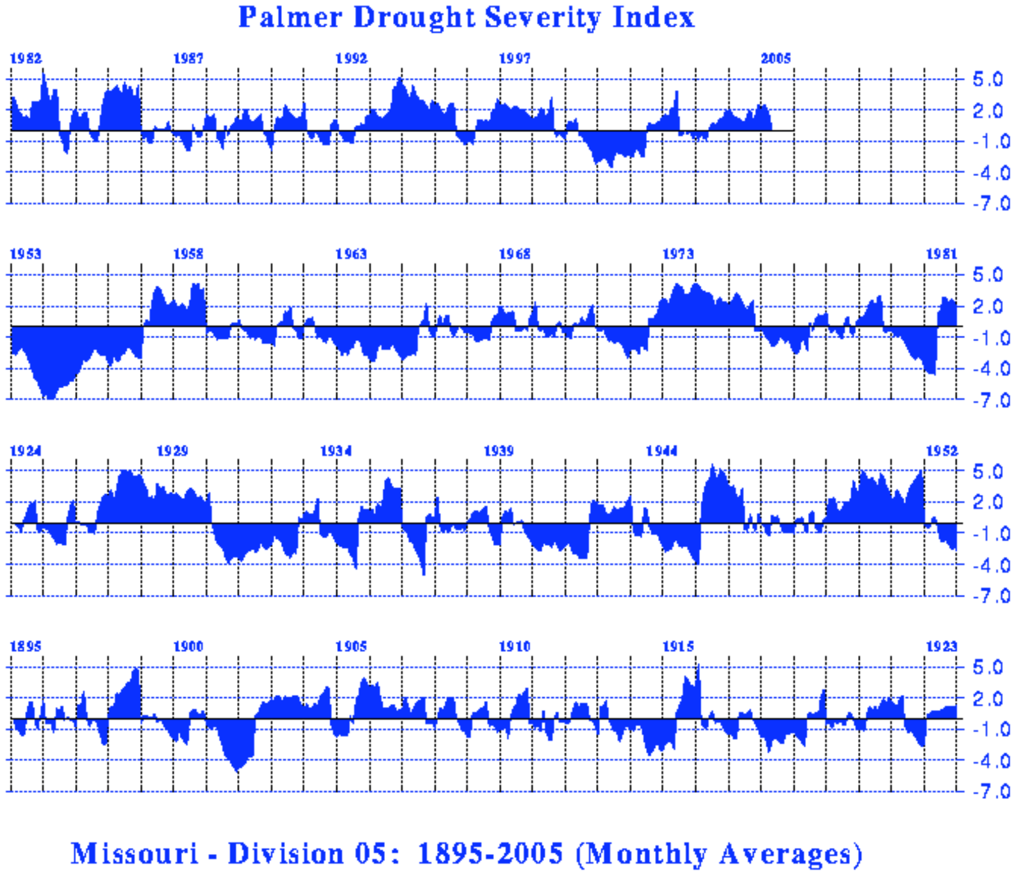

Figure 3. Palmer Drought Severity Index (PDSI) for southeastern Missouri, including the Mingo NWR, during 1895-2004. The horizontal line at "0" is considered normal moisture levels. Areas above the line represent adequate-to-surplus moisture for normal plant functioning, whereas areas below the line represent potential water stress. A drought severity index of -3 is generally considered to be a severe drought, likely reducing ozone uptake. The figure illustrates that moisture levels during the growing season have been generally adequate in recent years, except for drought at the end of 1999, followed by the season-long drought in 2000.

Surveys Dates and Locations

The Mingo National Wildlife Refuge was surveyed for ozone injury during September 3-5, 2004. Ten suitable survey sites had been selected in 1998, based on openness, accessibility, and presence of bioindicators; exact locations were refined during later visits. All sites (Figure 1) were visited in 2004, but data was not necessarily recorded at each site due to confounding plant disorders or adverse environmental conditions. In addition to these 10 specific areas, vegetation was observed in a subjective manner between sites.

The Mingo NWR had been surveyed twice in 1998: 5-9 August and 4-7 September. During other years, the refuge was only surveyed once: 29 July to 1 August 1999; 9-11 September 2000; 12-14 September 2003; and 3-5 September 2004. The 1998 survey allows a comparison of the increase in ozone injury from August to September, whereas the most comparable year-to-year evaluations use the September results.

Severity Rating

Each broadleaved plant evaluated for ambient ozone injury had to have foliage within reach; that is, trees were not climbed nor were pole-pruners used. The main dataset taken was the number of plants (expressed as a percentage) within a species that exhibited stipple, as compared to the total number of plants evaluated for that species. In addition, severity of injury (percentage of leaf tissue injured by ozone) was estimated on one or two selected bioindicators.

The ForestHealth Expert System had been used to train the investigator in estimating the amount of stipple on a leaf. The following evaluation system was utilized. For broadleaved tree species, the percentage of ozone injury was estimated on the oldest leaf on each of four branches, and the average value recorded. Then, the next oldest leaf was evaluated, and so on, until the five oldest leaves had been rated. For each herbaceous plant, each of the five (if present) oldest (basal) leaves of the plant was examined and the average percent stipple recorded. Each of the oldest five leaves on the current woody growth (canes) of vines, such as grapes, was rated and the average percent stipple recorded. On all species, only adaxial leaf surfaces were evaluated. Symptom severity on the adaxial surface of each leaf evaluated was estimated by assigning severity classes, based on the percentage of surface injured, of 0, 5, 10, 20, 40, 60, 80, 90, 95 and 100 %.

Slides or digital images were taken, if suitable subjects were observed, and sent to the FWS Air Quality Branch in Denver.

RESULTS AND DISCUSSION

Final Selection of Bioindicator Species

The initial selection of ozone-sensitive bioindicators in the Mingo NWR was made during and following the 1998 survey. However, additional bioindicator species were considered during each survey and the list modified accordingly. The bioindicators listed in this report were among the most common ozone-sensitive species that occurred in open areas and were observed during each survey year. Not all bioindicator species/genera listed were present at all sites.

Only approximate percentages (no decimal points) are given in the following text for incidence of injury prior to 2004.

Foliar Symptoms

Site 1 (Refuge Headquarters). During 2004, vegetation was examined in open areas near the headquarters building, entrance road, and parking lots (Figure 1, Site 1). This is the most useful survey site in the refuge, as there are many bioindicator plants present at this excellent, open location. The incidence and severity of ozone stipple was very light in 2004, being observed only on grape, where stipple was noted on 6 of 38 (15.8%) grapevines examined. Stipple was not observed in 2004 on the following number of other plants of interest: ash (34), blackberry (20), black cherry (6), black walnut (10), cucumbertree (20), flowering dogwood (10), redbud (30), sassafras (30), and sweetgum (10) (Table 1), as well as smooth sumac (4).

The incidence of ozone injury was much greater in 2003, when ozone injury was noted on approximately 11% of the ash plants, 9% of the flowering dogwoods, 19% of grapevines, and 14% of the winged sumac shrubs. In 2000, ozone stipple had been observed at this site on approximately 5% of the ash saplings, 6% of the blackberry plants, 20% of the cucumbertrees, and 24% of the wild grapevines.

In 1999, injury had been observed at Site 1 on the following percentage of plants examined: ash (3%), grape (13%), and winged sumac (10%).

During August 1998 ozone stipple was noted at this location on only two species: blackberry (3%) and sweetgum (10%). In September 1998 ozone injury was noted on the following percentages of the plants examined: ash (23%), black cherry (50%), cucumbertree (20%), flowering dogwood (10%), grape (20%), sassafras (9%), and sweetgum (4%). As expected, there was a great increase in the percentage of individuals showing stipple during the time period between August and September in these early surveys.

Here and throughout the general area in 2004, the foliage of some flowering dogwood trees and most winged sumac shrubs was turning red. However, the reddening was not as severe as in 1999 and 2003. Poison-ivy and box-elder leaves were slightly chlorotic. Defoliation was occurring on black walnut trees, but not ash. Leafspots were more common than in past years, especially on blackberry, black walnut, elm (blackspot), redbud, sassafras, sweetgum, and winged sumac. As in 2000 and 2003, many persimmon trees had dark leaf blotches on the leaves. Dutch elm disease and oak dieback occurred throughout the area.

As in many past years, leaf chewing by insects was common on various broadleaved trees and shrubs at this site and elsewhere. Webworm infestations were noted on black cherry saplings. Grape and redbud had very severe leafhopper-type injury; grape leaves also had insect gall infestations. Shingle oak leaves had severe leaf miner injury.

In addition, the general condition of the foliage of oaks, elm, various weeds, and species other than bioindicators was observed and noted to be free of ozone injury. There was a severe rust infection on an unknown weed growing under the power line.

A few scattered tree-of-heaven (*Ailanthus altissima*) seedlings and saplings were observed in the refuge. This fast-growing, invasive species exhibits stipple in response to ambient ozone, and should be monitored for ozone injury in the future.

Numerous species known to be sensitive to sulfur dioxide, including ash (34), blackberry (20), and giant ragweed (30) were examined and noted to be free of injury from this pollutant.

Site 2 (Scenic Overlook @ 1.1 mi). Vegetation was examined from the parking area to the overlook platform, and in the adjacent fields. The following species were noted to be free of ozone injury: ash (15), blackberry (30), grape (3), redbud (10), and sweetgum (4) (Table 1).

Severe leafspots were observed on the older leaves of redbud in 2004. Leaf blotches, or large leafspots, were noted on persimmon. Persimmon trees at this site also showed moderate webworm infestations. Insect injury was also common in elm and hickory. Boxelder foliage had moderate to severe insect injury.

Giant ragweed and blackberry, as well as ash, which are very sensitive to sulfur dioxide, were examined and noted to be free of injury from this pollutant.

During 2003, ozone injury was noted on 10% of the ash trees and seedlings, but not on other indicators. However, the foliage of the winged sumac shrubs was very red in 2003, confounding symptom rating. Ozone-induced injury was not observed on any bioindicators at this site during 1998-2000.

Site 3 (Hayfield @ 2.1 mi). In 2004 the numerous ash saplings and blackberry plants growing across the road from the large field were examined. Ozone injury was not observed on 30 ash plants or 30 blackberry plants (Table 1). Ash leaves had a large, dark leafspot, and ash trees were beginning to defoliate. Blackberry leaves exhibited light insect chewing and light leafhopper-type injury.

In 2003, the hayfield and adjacent area was under water and not examined. However, approximately 2% of the ash saplings across the road from the hayfield exhibited ozone injury. Ozone injury was not observed on 30 blackberry plants examined in 2003.

Ozone-induced injury was not observed on any bioindicators at this site during 1998-2000.

Site 4 (Very Large Hayfield @ 7.2 mi). In 2004 ozone injury was not observed on any bioindicators, including ash (20), blackberry (30), and sweetgum (10) (Table 1), as well as sycamore (4).

During 2003, approximately 9%) of the ash plants at this site had light ozone injury. Ozone injury was not observed on 30 blackberry plants, 10 sweetgum trees, or 4 sycamores in 2003. As in past years, the sycamores had moderate to severe leafhopper-type injury on the leaves. A small patch of elderberry plants, which are excellent bioindicators for ozone injury, had been observed in past years at 0.7 miles beyond site 4. However, the elderberry plants were no longer present at this site in 2003 (or in 2004), probably having been removed during mowing.

Ozone-induced injury was not observed on any bioindicators at this site during August 1999-2000. In September 1998 ozone injury was observed on 27% of the ash plants.

Site 5 (Cow Creek Overlook @ 9.0 mi). This site was judged too shady for full ozone symptom development and was not used as an indicator site in 2000 or 2003-2004 and should be abandoned as a survey site. In fact, the fragrant sumac shrubs that had been present in past years at Fry Bluff Overlook, were no longer present, perhaps having been mowed.

In 2003, fragrant sumac shrubs were examined at the Fry Bluff Overlook @ 12.7 miles, designated as Site 5a. These shrubs were growing in partial shade, but were evaluated since they are very sensitive to ozone, and since this species was not common at most survey sites. However, the fragrant sumacs did not exhibit ozone injury during 1999, 2000, or 2003. This site may be too shaded to adequate symptom development.

Site 6 (Bridge). In 2004 this site was judged to be too shaded and was not evaluated. In addition, the few common milkweeds that had been present at the sharp bend in past years were growing in deep shade and were not evaluated.

This site was also judged to be too shady in 1999 and not evaluated. However, in 2000 a stand of common milkweed was observed along the road going to May Pond. Therefore, the plot was moved a short distance and re-established closer to May Pond, even though the milkweeds did not exhibit ozone injury that year. However, by 2003 these milkweeds had been overgrown by other vegetation and could not be evaluated. These milkweeds were not present in 2004.

The usefulness of this site should be judged on a year-to-year basis in future years.

Site 7 (Swamp Overlook @ 13.9 mi). In 2004, none of the 14 ash examined at this site exhibited ozone injury.

It was very interesting that all 20 of the wisteria examined at this site exhibited upper leaf surface, dark, stipple that was very similar, if not identical, to that caused by ozone. As stated in my 2000 report "…30 of 40 wisteria vines, possibly Wisteria frutescens (L.) Poir. (=Kraunhia frutescens (L.) Greene) at this location exhibited classic stipple identical to that caused by ozone. This species was not encountered on other plots, and is at the edge of its range within the Mingo NWR … we have never exposed this species to ozone under controlled conditions to induce and to describe ozone-induced symptoms. Nevertheless, wisteria may be the best indicator to detect ozone injury at this location." This is still true.

In 2003, approximately 8% of the ash at this site had ozone injury. Ozone-induced injury was not observed on any bioindicators at this site during August 1998, 1999, or 2000. However, during September 1998 ozone injury was noted on 1 of 5 ash examined.

Sites 8-9 (Large Open Fields Near Fox Pond, @ 15.1 mi). This survey area was comprised of several very large fields that contained separate patches of common milkweed. A short history of this site follows.

During 1998 and 1999, many hundreds of common milkweeds were present in these fields. In 1998, a sample of 100 milkweed plants was evaluated, but ozone injury was not observed. In 1999, 347 milkweed plants were evaluated, and ozone injury was recorded on approximately 10% of the plants. During the 2000 survey, there were few milkweed plants with foliage suitable for evaluation of stipple. Only 10 milkweeds were evaluated, and exhibited no ozone injury. In 2003 an extensive effort was made to locate milkweeds at this site, as well in adjacent fields, and 100 scattered milkweeds were found that were considered marginally suitable for survey purposes. Ozone injury was not observed on these milkweeds in 2003.

By 2004, common milkweeds could not be found at this location, perhaps having been mowed, or losing in the race for succession, and are becoming less and less common. Therefore, common milkweeds were rated in other nearby fields, where 39 scattered plants were located and evaluated. However, all 39 plants were missing their lower leaves, which are most sensitive to ozone. Nevertheless, 2 of 39 (5.1%) of the plants exhibited a light stipple on the oldest of the remaining leaves.

Site 10 (Large Field @ 21.3 mi). This site was moved in 1999 to a new area designated as Site 11.

Site 11 (Large Field @ 23.5 mi). Unfortunately, this abandoned field, which had contained a large number of bioindicators, had just been completely plowed and disked, and will likely be planted in a wildlife crop. There was nothing present except bare exposed soil. If this survey is continued in future years, considerable time should be spent in the area finding a substitute for this site.

In 2000 ozone-induced injury had been observed on 4 blackberry plants and 1 sweetgum seedling at this site. In addition, approximately 30 of 40 (75%) of the wisteria vines at this location exhibited ozone stipple in 2000. Again, wisteria may be a good indicator to detect ozone injury within the Mingo NWR.

In 1999 ozone-induced injury was not observed on bioindicators at this location.

Date/Plot	Ash	Black Cherry	Black-berry	Cucum-bertree	Dogwood (Flowering)	Elder-berry	Grape (Wild)	Milkweed (Common)	Red-bud	Sassa-fras	Sweet-gum	Sumac (Fragrant)	Sumac (Winged)
Aug - 1998													
Total	0/70	0/4	1/60	1/10			0/26	0/100		0/15	1/60		
Percent	0.0%	0.0%	1.7%	10.0%			0.0%	0.0%		0.0%	1.7%		
Sept - 1998													
Total	25/137	2/7		1/6	1/10		6/30	30/51		3/39	1/22		
Percent	18.2%	28.6%		16.7%	10.0%		20.0%	58.8%		0.1	4.5%		
Aug - 1999													
Total	1/98	0/6	0/180	0/3	0/5	0/14	2/30	33/347	0/30	0/13	0/125	0/12	3/64
Percent	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.7%	9.5%	0.0%	0.0%	0.0%	0.0%	4.7%
Sept -2000													
Total	3/114	0/10	8/192	3/15	0/10	0/10	4/31	0/10		0/28	1/90	0/20	2/41
Percent	2.6%	0.0%	4.2%	20.0%	0.0%	0.0%	12.9%	0.0%		0.0%	1.1%	0.0%	4.9%
Sept - 2003													
Total	13/180	0/7	0/120	0/30	1/11	0/24	4/22	0/100	0/40	0/35	0/34	0/70	5/35
Percent	7.2%	0.0%	0.0%	0.0%	9.1%	0.0%	18.2	0.0%	0.0%	0.0%	0.0%	0.0%	14.3%
Sept - 2004													
1	0/34	0/6	0/20	0/20	0/10		6/38		0/30	0/30	0/10		
2	0/15		0/30				0/3		0/10		0/4		
3	0/30		0/30										
4	0/20		0/30								0/10		
5a													
6													
7	0/14												
8 & 9								2/39					
10													
11													
Sept - 2004													
Total	0/113	0/6	0/110	0/20	0/10		6/41	2/39	0/40	0/30	0/24		
Percent	0.0%	0.0%	0.0%	0.0%	0.0%		14.6%	5.1%	0.0%	0.0%	0.0%		

Table 1. Summary of observations made during the 2004 survey at the Mingo National Wildlife Refuge. Numbers in table refer to number of plants with ozone-induced injury as compared to the total number of plants evaluated for that species, followed by percentages. The 2004 results are compared with the 1998-2000 and 2003 observations. Bioindicators, as well as other common plant species, are listed.

Confounding Factors

In addition to variability among species in sensitivity to ozone, other factors confound the results of such field surveys. For example, milkweed plants could not be evaluated year-to-year in a consistent manner. Milkweeds growing in fields away from the roads were at times defoliated by caterpillars, and/or were often overgrown and replaced or shaded as the old fields in the refuge underwent natural succession. Also, common milkweeds usually grow in vegetative clones, in which the individual plants are all of the same genetic sensitivity to ozone. This latter characteristic requires that survey sites be spaced properly, so as not to rate only individuals of the same clone. Nevertheless, as long as one considers confounding factors, it is still possible to use bioindicators such as ash, grape, or common milkweed in ozone-injury surveys.

In general, one might assume that greater ozone-induced stipple would be manifested in years with greater ambient ozone concentrations. However, these general relationships can be completely overshadowed by extreme environmental conditions, such as severe droughts. For example, extremely high ozone levels were observed across eastern USA during the summer of 1988. One might have concluded that severe ozone injury would also have occurred on sensitive plant species in the East in that year. However, in reality the severe drought and resultant water stress caused in stomatal closure in plants, very little uptake of ozone, and very little ozone injury in 1988 throughout the East.

Little is known regarding the sensitivity of wetland plants to ozone. Likewise, little is known about the ozone sensitivity of "spring ephemerals". Since the ozone levels at the Mingo NWR have often been quite high by June, it is possible that unnoticed ozone injury occurs on ozone-sensitive plants that emerge and complete their life cycle by early summer within the refuge, prior to the surveys.

SUMMARY

This 2004 survey revealed that ozone injury was present on vegetation within the boundaries of the Mingo NWR, a refuge that contains a Class I air quality area. The cumulative, ambient, ozone dose prior to 2004 survey (Figure 2) was very low, barely exceeding threshold levels needed to cause ozone injury on sensitive vegetation. The overall incidence of observed ozone injury was also very low in 2004.

Using only the September survey results (not considering the August 1998 and the 1999 surveys), the most ozone injury during any survey year occurred in 1998, a year of relatively high ozone levels (Figure 2) and adequate moisture (Figure 3). The amount of ozone injury during 2000 and 2003 varied with species, and injury in 1998-1999 was greater in September than in August. The incidence of ozone injury in 2004 was very light.

These ozone-related survey results should prove useful to the FWS when making air quality management decisions related to the review of Prevention of Significant Deterioration (PSD) permits.

If this refuge is visited in future years, it is recommended that the visit be made during the first week of September.

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Appendix

Symbol	Scientific Name	Common Name
ACOPR	*Acmella oppositifolia* (Lam.) R.K. Jansen var. *repens* (Walt.)	Oppositeleaf spotflower
ACNE2	*Acer negundo* L.	Box elder
ACRUD	*Acer rubrum* L.	Red maple
ACRUD	*Acer rubrum* var. *drummondii* (Hook. & Arn. ex Nutt.) Sarg.	Drummond's maple
ACSA2	*Acer saccharinum* L.	Silver maple
ACSA3	*Acer saccharum* Marsh.	Sugar maple
ADPE	*Adiantum pedatum* L.	Northern maidenhair
AEGL	*Aesculus glabra* Willd.	Ohio buckeye
AEPA	*Aesculus pavia* L.	Red buckeye
AIAL	*Ailanthus altissima* (P.Mill.) Swingle	Tree-fo-heaven
ALJU	*Albizia julibrissin* Durazz.	Silktree
ALSE2	*Alnus serrulata* (Ait.) Willd.	Hazel Alder
AMAR3	*Amelanchier arborea* (Michx. F.) Fern.	Common serviceberry
AMCO2	*Ampelopsis cordata* Michx.	Heartleaf peppervine
AMFR	*Amorpha fruticosa* L.	Desert false indigo
APAM	*Apios americana* Medik.	Groundnut
ARGI	*Arundinaria gigantea* (Walt.) Muhl.	Giant cane
ARLA6	*Aristida lanosa* Muhl. ex Ell.	Woollysheath threeawn
ARSP2	*Aralia spinosa* L.	Devil's walkingstick
ASPE	*Asclepias perennis* Walt.	Aquatic milkweed
ASPL	*Asplenium platyneuron* (L.) B.S.P.	Ebony spleenwort
ASRH2	*Asplenium rhizophyllum* L.	Walking fern
ASSY	*Asclepias syriaca* L.	Common milkweed
ASTR	*Asimina triloba* (L.) Kuntze.	Pawpaw
AZME	*Azolla mexicana* Schlecht. & Cham. ex K. Presl	Mexican mosquitofern
BAPA2	*Bartonia paniculata* (Michx.) Muhl.	Twining screwstem
BENI	*Betula nigra* L.	River birch
BICA	*Bignonia capreolata* (L.) Bureau.	Crossvine
BODI2	*Botrychium dissectum* Spreng.	Cutleaf grapefern
BOVI	*Botrychium virginianum* (L.) Sw.	Rattlesnake fern
BROV4	*Brunnichia ovata* (Walt.) Shinners.	American buckwheat vine
CAAL27	*Carya alba* Nutt.	Mockernut hickory
CAAQ2	*Carya aquatica* (Michx. f.) Nutt.	Water hickory
CACA	*Cabomba caroliniana* Gray	Carolina fanwort
CACA18	*Carpinus caroliniana* Walt.	American hornbeam
CACO15	*Carya cordiformis* (Wang.) K. Koch.	Bitternut hickory
CALA21	*Carya laciniosa* (Michx.f.) Loud.	Shellbark hickory
CALO6	*Carex louisianica* Bailey	Louisiana sedge
CALY2	*Calycocarpum lyonii* (Pursh) Gray.	Cupseed
CAMO83	*Castanea mollissime* Blume.	Chinese chestnut
CAOV2	*Carya ovata* (Mill.) K. Koch.	Shagbark hickory
CARA2	*Campsis radicans* (L.) Seem. ex Bureau	Trumpet creeper
CATE9	*Carya texana* Buckl.	Black hickory
CEAM	*Ceanothus americanus* L.	New Jersey tea
CECA4	*Cercis canadensis* L.	Eastern redbud
CELA	*Celtis laevigata* Willd.	Sugarberry
CEOC	*Celtis occidentalis* L.	Common hackberry
CEOC2	*Cephalanthus occidentalis* L.	Common buttonbush
CESC	*Celastrus scandens* L.	American bittersweet
CHLA2	*Cheilanthes lanosa* (Michx.) D.C. Eat.	Hairy lipfern

CLCR	*Clematis crispa* L.	Swamp leather flower
CLMA4	*Clitoria mariana* L	Atlantic pigeonwings
CLVI5	*Clematis virginiana* L.	Devil's darning needles
COAM3	*Corylus americana* Walt.	American hazelnut
COCA	*Cocculus carolinus* (L.) DC.	Carolina coralbeads
COFL2	*Cornus florida* L.	Flowering dogwood
COFO	*Cornus foemina* P. Mill	Stiff dogwood
CORYL	*Corylus* L.	Hazelnut
CRCA	*Crataegus calpodendron* (Ehrh.) Medic.	Pear hawthorn
CRCA2	*Crataegus curs-galli* L.	Cockspur hawthorn
CRVI2	*Crataegus viridis* L.	Green hawthorn
CUSCU	*Cuscuta* L.	Dodder
CYBU3	*Cystopteris bulbifera* (L.) Bernh.	Bulblet bladderfern
CYDI2	*Cynosciadium digitatum* DC.	Finger dogshade
CYFR2	*Cystopteris fragilis* (L.) Bernh.	Brittle bladderfern
DEAC4	*Deparia acrostichoides* (Sw.) M. Kato	Silver false spleenwort
DIPY	*Diplazium pycnocarpon* (Speng.) Broun	Glade fern
DIQU	*Dioscorea quaternata* J.F. Gmel.	Fourleaf yam
DIVI3	*Diodia virginiana* L.	Virginia buttonweed
DIVI5	*Diospyros virginiana* L.	Common persimmon
EPVI2	*Epifagus virginiana* (L.) W. Bart.	Beechdrops
ERPR5	Eryngium prostratum Nutt. ex DC.	Creeping eryngo
EUAT3	*Euonymus atropurpurea* Jacq.	Eastern wahoo
FAGR	*Fagus grandifolia* Ehrh.	American beech
FOAC	*Forestiera acuminata* (Michx.) Poir.	Eastern swamp privet
FRAM2	*Fraxinus americana* L.	White ash
FRCA13	*Frangula caroliniana* Walt.	Carolina buckthorn
FRPE	*Fraxinus pennsylvanica* Marsh	Green ash
FRPR	*Fraxinus profunda* (Bush) Bush	Pumpkin ash
GLAQ	*Gleditsia aquatica* Marsh.	Water locust
GLTR	*Gleditsia triacanthos* L.	Honeylocust
GYDI	*Gymnocladus dioicus* (L.) K. Koch.	Kentucky coffeetree
HEMI3	*Helianthus microcephalus* Torr. & Gray	Small woodland sunflower
HYAR	*Hydrangea arborescens* L.	Wild hydrangea
HYCA9	*Hymenocallis caroliniana* L. Herbert	Carolina spiderlily
HYHYM	*Hypericum hypericoides* (L.) Crantz ssp. *multicaule* (Michx.)	St. Andrew's cross
HYUN	*Hydrolea uniflora* Raf.	Oneflower false fiddleleaf
ILDE	*Ilex decidua* Walt.	Possumhaw
ILOP	*Ilex opaca* Ait.	American holly
IPHE	*Ipomoea hederacea* Jacq.	Ivyleaf morning-glory
IPLA	*Ipomoea lacunosa* L.	Whitestar
IPPA	*Ipomoea pandurata* (L.) G.F.W. Mey.	Man of the earth
IRFU	*Iris fulva* Ker-Gawl.	Copper iris
ITVI	*Itea virginica* L.	Virginia sweetspire
JUCI	*Juglans cinerea* L.	Butternut
JUNI	*Juglans nigra* L.	Black walnut
JUOV	*Justicia ovata* (Walt.) Lindau	Looseflower waterwillow
JUVI	*Juniperus virginiana* L.	Eastern redcedar
LEFL	*Leitneria floridana* Chapman	Corkwood
LIBE3	*Lindera benzoin* (L.) Blume.	Northern spicebush
LIST2	*Liquidambar styraciflua* L.	Sweetgum
LITU	*Liriodendron tulipifera* L.	Tuliptree
LOJA	*Lonicera japonica* Thunb.	Japanese honeysuckle
LUGL	*Ludwigia glandulosa* Walt.	Cylindricfruit primrosewillow

LYRA3	*Lysimachia radicans* Hook.	Trailing yellow loosestrife
MAAC	*Magnolia acuminata* (L.) L.	Cucumber-tree
MAIOI	*Malus ioensis* (Wood) Britt. var. *ioensis*	Prairie crabapple
MAPO	*Maclura pomifera* (Raf.) Schneid.	Osage orange
MECA3	*Menispermum canadense* L.	Common moodseed
MISC	*Mikania scandens* (L.) Willd.	Climbing hempvine
MOAL	*Morus alba* L.	White mulberry
MORU2	*Morus rubra* L	Red mulberry
MORUS	*Morus L.*	Mulberry
NYAQ2	*Nyssa aquatica* L.	Water tupelo
NYSY	*Nyssa sylvatica* Marsh.	Blackgum
OBVI	*Obolaria virginica* L.	Virginia pennywort
OLUN	*Oldenlandia uniflora* L.	Clustered mille graines
OPVU	*Ophioglossum vulgatum* L.	Southern adderstongue
OSVI	*Ostrya virginiana* (Mill.) K. Koch.	Hop hornbeam
PALU2	*Passiflora lutea* L.	Yellow passionflower
PAQU2	*Parthenocissus quinquefolia* (L.) Planch.	Virginia creeper
PAVI5	*Parthenocissus vitaceae* (Knerr) Hitchc.	Woodbine
PEAT2	*Pellaea atropurpurea* (L.) Link	Purple cliffbrake
PHHE11	*Phegopteris hexagonoptera* (Michx.)	Broad beechfern
PHME13	*Photina melanocarpa* (Michx.) Robertson & Phipps	Black Chockberry
PIEC2	*Pinus echinata* Mill.	Shortleaf pine
PIST	*Pinus strobus* L.	White pine
PLAQ	*Planera aquatica* (Walt.) J.F. Gmel.	Planertree
PLCA7	*Pluchea camphorata* (L.) DC.	Camphor pluchea
PLOC	*Platanus occidnetalis* L.	American sycamore
PLPOP	*Pleopeltis polypodioides* (L.) Andrews & Windham ssp. *polypodioides*	Resurrection fern
POAC4	*Polystichum acrostichoides* (Michx.) Schott	Christmas fern
POAM3	*Polygonella americana* (Fisch. & C.A. Mey.) Small	Southern jointweed
PODE3	*Populus deltoides* Marsh.	Eastern cottonwood
POHE4	*Populus heterophylla* L.	Swamp cottonwood
POPUL	*Populus* L.	Cottonwood
POSC3	*Polygonum scandens* L.	Climbing false buckwheat
PRME	*Prunus mexicana* S. Wats.	Mexican Plum
PRSE2	*Prunus serotina* Ehrh.	Black cherry
PTELE	*Ptelea* L.	Hoptree
QUAL	*Quercus alba* L.	White oak
QUBI	*Quercus bicolor* Willd.	Swamp white oak
QUCO2	*Quercus coccinea* Muenchh.	Scarlet oak
QUIM	*Quercus imbricaria* Michx.	Shingle oak
QULY	*Quercus lyrata* Walt.	Overcup oak
QUMA2	*Quercus macrocarpa* Michx.	Bur oak
QUMA3	*Quercus marilandica* Muenchh.	Blackjack oak
QUMI	*Quercus michauxii* Nutt.	Swamp chestnut oak
QUMU	*Quercus muehlenbergii* Engelm.	Chinkapin oak
QUNI	*Quercus nigra* L.	Water oak
QUPA2	*Quercus palustris* Muenchh.	Pin oak
QUPA5	*Quercus pagoda* Raf.	Cherrybark oak
QUPH	*Quercus phellos* L.	Willow oak
QURU	*Quercus rubra* L.	Northern red oak
QUSH	*Quercus shumardii* Buckl.	Shumard's oak
QUST	*Quercus stellata* Wang.	Post oak
QUVE	*Quercus velutina* Lam.	Black oak

RHAR4	*Rhus aromatica* Ait.	Fragrant sumac
RHCOL2	*Rhus copallinum* L.var. *latifolia* Engl.	Winged sumac
RHGL	*Rhus glabra* L.	Smooth sumac
RHMA6	*Rhynchospora macrostachya* Torr. ex Gray	Tall horned beaksedge
RIMI	*Ribes missouriense* Nutt.	Missouri gooseberry
ROCA4	*Rosa carolina* L.	Carolina rose
ROMU	*Rosa multiflora* Thunb.	Multiflora rose
ROPA	*Rosa palustris* Marsh.	Swamp rose
ROPS	*Robinis pseudoacecia* L.	Black locust
ROSE2	*Rosa setigera* Michx.	Climbing rose
RUAL	*Rubus allegheniensis* Porter.	Allegheny blackberry
RUBUS	*Rubus* L.	Blackberry
RUFL	*Rubus flagellaris* Willd.	North dewberry
SAAL5	*Sassafras albidum* (Nutt.) Nees.	Sassafras
SANI	*Salix nigra* Marsh.	Black willow
SANIC4	*Sambucus nigra* L. ssp. *canadensis* (L.) R. Bolti	Common elderberrry
SILAO	*Sideroxylon lanuginosum* (Michx) ssp. *Oblongifolium* (Nutt.)	Gum bully
SMBO2	*Smilax bona-nox* L.	Sawbrier
SMGL	*Smilax glauca* Walt.	Cat greenbrier
SMRO	*Smilax rotundifolia* L.	Roundleaf greenbrier
SMTA2	*Smilax tamnoides* L. var. *hispida* (Muhl.) Fern.	Bristly greenbrier
SODU	*Solanum dulcamara* L.	Climbing nightshade
SPPE3	*Sphenopholis pensylvanica* (L.) A.S. Hitchc.	Swamp wedgescale
STAM4	*Sytyrax americanus* Lam.	American snowbell
STTR	*Staphylea trifolia* L.	American bladdernut
SYOR	*Symphoricarpos orbiculatus* Moench.	Coralberry
TADI2	*Taxodium distichum* (L.) L.C. Rich.	Baldcypress
THDE	*Thalia dealbata* Fraser ex Roscoe	Powdery alligatorflag
TILIA	*Tilia* L.	Basswood
TORA2	*Toxicodendron radicans* (L.) Kuntze.	Eastern poison ivy
TRDI	*Trachelospermum difforme* (Walt.) Gray	Climbing dogbane
TRSE5	*Trichostema setaceum* Houtt.	Narrowleaf bluecurls
ULAL	*Ulmus alata* Michx.	Winged elm
ULAM	*Ulmus americana* L.	American elm
ULRU	*Ulmus rubra* Muhl.	Slippery elm
VAAN	*Vaccinium angustifolium* Ait.	Lowbush blueberry
VAAR	*Vaccinium arboreum* Marsh.	Farkleberry
VAST	*Vaccinium stamineum* L.	Deerberry
VIAE	*Vitis aestivalis* Michx.	Summer grape
VIBUR	*Viburnum* L.	Viburnum
VICH4	*Viola chamissoniana* Gingins	Olopu
VICI2	*Vitis cinerea* (Engelm.) Millard	Graybark grape
VILA4	*Viola lanceolata* L.	Bog white violet
VIPA7	*Vitis palmata* Vahl	Catbird grape
VIRU	*Viburnum rufidulum* Raf.	Rusty blackhaw
VITIS	*Vitis* L.	Grape
VIVU	*Vitis vupina* L.	Frost grape
WIFR	*Wisteria frutescens* (L.) Poir.	American wisteria
WOGL2	*Wolffiella gladiata* (Hegelm.) Hegelm.	Florida mudmidget